

WHAT IS CLAIMED IS:

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5 1. A method of shaping a semisolid metal, in which a liquid alloy having crystal nuclei at a temperature not lower than the liquidus temperature or a partially solid, partially liquid alloy having crystal nuclei at a temperature not lower than a molding temperature is fed into an insulated vessel having a heat insulating effect, held in said insulated vessel for a period from 10 5 seconds to 60 minutes as it is cooled to the molding temperature where a specified fraction liquid is established, thereby crystallizing fine primary crystals in the alloy solution, and the alloy is fed into a forming mold, where it is shaped under pressure.

15 2. A method according to claim 1, wherein the crystal nuclei are generated by contacting the molten alloy with a surface of a jig at a temperature lower than the melting point of said alloy which has been held 20 superheated to less than 300° above the liquidus temperature.

25 3. A method according to claim 2, wherein the jig with which the melt is to be contacted is a metallic or nonmetallic jig, or a metallic jig having a surface coated with a nonmetallic material or semiconductor, or a metallic jig composited with a nonmetallic material or semiconductor, with said jig being adapted to be 30 coolable from either inside or outside.

35 4. A method according to claim 1 or 2, wherein the crystal nuclei are generated by applying vibrations to the molten metal in contact with either the jig or the insulated vessel or both.

5. A method according to claim 1 or 2, wherein the alloy is an aluminum alloy of a composition within a maximum solubility limit or a hypoeutectic aluminum

alloy of a composition at or above a maximum solubility limit.

6. A method according to claim 1 or 2, wherein the alloy is a manganese alloy of a composition within a maximum solubility limit.

7. A method according to claim 5, wherein the aluminum alloy has 0.001% - 0.01% B and 0.005% - 0.3% Ti added thereto.

8. A method according to claim 6, wherein the magnesium alloy has 0.005% - 0.1% Sr added thereto, or 0.01% - 1.5% Si and 0.005% - 0.1% Sr added thereto, or 0.05% - 0.30% Ca added thereto.

9. A method according to claim 7, wherein a molten aluminum alloy held superheated less than 100°C above the liquidus temperature is directly poured into the insulated vessel without using a jig.

10. A method according to claim 8, wherein a molten magnesium alloy held superheated to less than 100°C above the liquidus temperature is directly poured into the insulated vessel without using a jig.

11. A method of shaping a semisolid metal, in which liquid alloy having crystal nuclei that has been superheated by a degree ( $X^{\circ}$ ) of less than 10°C above the liquidus line is held in an insulated vessel for a period from 5 seconds to 60 minutes as it is cooled to a molding temperature where a specified fraction liquid is established, such that the cooling from the initial temperature at which said alloy is held in said insulated vessel to its liquidus temperature is completed within a time shorter than the time Y (in minutes) calculated by the relation  $Y=10-X$  and that the period of cooling from said initial temperature to a

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temperature 5° lower than said liquidus temperature is not longer than 15 minutes, whereby fine primary crystals are crystallized in the alloy solution, which is then fed into a forming mold, where it is shaped under pressure.

10 12. A method of shaping a semisolid metal, in which a partially solid, partially liquid alloy having crystal nuclei at a temperature not lower than a molding temperature is held within an insulated vessel for a period from 5 seconds to 60 minutes as it is cooled to the molding temperature where a specified fraction liquid is established, such that the period of cooling from the initial temperature at which said alloy is  
15 held in said insulated vessel to a temperature 5° lower than its liquidus temperature is not longer than 15 minutes, whereby fine primary crystals are crystallized in the alloy solution, which is then fed into a forming mold, where it is shaped under pressure.

20 13. A method according to claim 11 or 12, wherein the crystal nuclei are generated by holding the molten alloy superheated to less than 300° above the liquidus temperature and contacting the melt with a surface of a  
25 jig at a lower temperature than its melting point.

30 14. An apparatus for producing a semisolid forming metal having fine primary crystals dispersed in a liquid phase, which comprises a nucleus generating section that causes a molten metal to contact a cooling jig to generate crystal nuclei in the solution and a crystal generating section having an insulated vessel in which the metal obtained in said nucleus generating section is held as it is cooled to a molding  
35 temperature at which said metal is partially solid, partially liquid.

15. An apparatus according to claim 14, wherein the

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cooling jig in the nucleus generating section is either an inclined flat plate that has an internal channel for a cooling medium and that has a pair of weirs provided on the top surface parallel to the flow of the melt, or a cylindrical or semicylindrical tube.

10 16. A method of shaping a semisolid metal, in which a liquid alloy having crystal nuclei at a temperature not lower than the liquidus temperature or a partially solid, partially liquid alloy having crystal nuclei at a temperature not lower than a molding temperature is poured into a vessel so that it is cooled to a temperature at which a fraction solid appropriate for shaping is established, said vessel being adapted to be  
15 heatable or coolable from either inside or outside, being made of a material having a thermal conductivity of at least 1.0 kcal/hr·m·°C (at room temperature) and being held at a temperature not higher than the liquidus temperature of said alloy prior to its  
20 pouring, and in which said alloy is poured into said vessel in such a manner that fine, nondendritic primary crystals are crystallized in said alloy solution and that said alloy is cooled rapidly enough to be provided with a uniform temperature profile in said vessel, and  
25 said alloy, after being cooled, is fed into a forming mold, where it is shaped under pressure.

30 17. A method according to claim 16, wherein the step of cooling said alloy is performed with the top and bottom portions of the vessel being heated by a greater degree than the middle portion or heat-retained with a heat-retaining material having a thermal conductivity of less than 1.0 kcal/hr·m·°C or with either the top or bottom portion of the vessel being heated while the  
35 remainder is heat-retained.

18. A method according to claim 16, wherein the step of cooling said alloy is performed with the vessel

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holding said alloy being accommodated in an outer vessel that is capable of accommodating said alloy holding vessel and that has a smaller thermal conductivity than said holding vessel, or that has a thermal conductivity equal to or greater than that of said holding vessel and which has a higher initial temperature than said holding vessel, or that is spaced from said holding vessel by a gas-filled gap, at a sufficiently rapid cooling rate to provide a uniform temperature profile through the alloy in said holding vessel no later than the start of the shaping step.

19. In a method of managing the temperature of a semisolid metal slurry for use in molding equipment in which a molten metal containing a large number of crystal nuclei is poured into a vessel, where it is cooled to produce a semisolid metal slurry containing both a solid and a liquid phase in specified amounts, said slurry being subsequently fed into a molding machine for shaping under pressure, the improvement wherein the vessel for holding said molten metal is temperature-managed such as to establish a preset desired temperature prior to the pouring of said molten metal and such that said molten metal is cooled at an intended rate after said molten metal is poured into said vessel.

20. An apparatus for managing the temperature of a semisolid metal slurry to be used in molding equipment in which a molten metal containing a large number of crystal nuclei is poured from a melt holding furnace into a vessel, where it is cooled to produce a semisolid metal slurry containing both a solid and a liquid phase in specified amounts and in which said slurry is directly fed into a molding machine for shaping under pressure, which apparatus comprising the vessel for comprising the vessel for holding said molten metal, a vessel temperature control section for

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5 managing the temperature of said vessel, a semisolid metal cooling section for managing the temperature of the as-poured molten metal such that it is cooled at an intended rate, and a vessel transport mechanism comprising basically a robot for gripping, moving and transporting said vessel and a conveyor for carrying, moving and transporting said vessel.

10 21. An apparatus according to claim 20, wherein the vessel temperature control section comprises a vessel cooling furnace for cooling the vessel at an ambient temperature not higher than a target temperature for the vessel and a vessel heat-retaining furnace for holding the vessel at an ambient temperature equal to  
15 said target temperature

20 22. An apparatus according to claim 20, wherein the semisolid metal cooling section comprises a semisolid metal slowly cooling furnace and a semisolid metal slowly cooling furnace for managing the temperature in itself to be higher than the temperature in said semisolid metal cooling furnace.

25 23. An apparatus according to claim 22, wherein the semisolid metal cooling furnace is such that the area around the vessel carried on the conveyor device moving to pass through said furnace is partitioned into three regions, the upper, middle and lower parts, by means of two pairs of heat insulating plates, one pair  
30 consisting of an upper right and an upper left plate and the other pair consisting of a lower right and a lower left plate, with a heater being installed in both said upper and lower parts for heating said two parts at a higher temperature than hot air to be supplied to  
35 said central part.

24. An apparatus according to claim 22, wherein a preheating furnace is installed at a stage prior to the

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semisolid metal cooling furnace to ensure that both a plinth having a lower thermal conductivity than said vessel and which carries said vessel before it is directed to said semisolid metal cooling furnace and a lid having a lower thermal conductivity than said vessel and which is to be placed to cover it after it accommodates said molten metal are preheated by being moved to pass through said preheating furnace in advance.

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25. An apparatus according to claim 24, wherein the semisolid metal cooling furnace is equipped with a control unit with which the temperature or the velocity of hot air to be supplied into said semisolid metal cooling furnace is controlled to vary with the lapse of time.

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26. An apparatus according to claim 22, wherein the semisolid metal cooling furnace comprises an array of housings each accommodating the vessel as it contains the molten metal and being equipped with an openable cover and hot air feed/exhaust pipes, as well as a mechanism by which a receptacle for carrying said vessel is rotated about a vertical shaft.

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27. An apparatus according to claim 26, wherein the housing are each equipped with a vibrator for vibrating the receptacle.

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28. An apparatus according to claim 24, wherein the semisolid metal cooling furnace for treating the molten metal as poured into a vessel having a thermal conductivity of at least  $1.0 \text{ kcal/hr} \cdot \text{m} \cdot ^\circ\text{C}$  is supplied with hot air having a temperature in the range from  $150^\circ\text{C}$  to  $350^\circ\text{C}$  for aluminum alloys and from  $200^\circ\text{C}$  to  $450^\circ\text{C}$  for magnesium alloys.

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29. An apparatus according to claim 24, wherein the

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5 semisolid metal cooling furnace for treating the molten metal as poured into a vessel having a thermal conductivity of less than 1.0 kcal/hr.m.<sup>2</sup>.°C is supplied with hot air having a temperature in the range from 50°C to 200°C for aluminum alloys and from 100°C to 250°C for magnesium alloys.

10 30. A method according to claim 1 or 2, wherein the molten metal as poured into the insulated vessel is isolated from the ambient atmosphere by closing the top surface of said vessel with an insulating lid having a heat insulating effect as long as said molten metal is held within said vessel until the molding temperature is reached.

15 31. A method according to claim 1 or 2, wherein the alloy is a zinc alloy.

20 32. A method according to claim 1 or 2, wherein the alloy is a hypereutectic Al-Si alloy having 0.005% - 0.03% P added thereto or a hypereutectic Al-Si alloy containing 0.005% - 0.03% P and having either 0.005% - 0.03% Sr or 0.001% - 0.01% Na or both added thereto.

25 33. A method according to claim 1 or 2, wherein the alloy is a hypoeutectic Al-Mg alloy containing Mg in an amount not exceeding a maximum solubility limit and which has 0.3% - 2.5% Si added thereto.

30 34. A method according to claim 1 or 2, wherein the pressure forming is accomplished with the alloy being inserted into a container on an extruding machine.

35 35. A method according to claim 34, wherein the extruding machine is of either a horizontal or a vertical type or of such a horizontal type in which the container changes position from being vertical to horizontal before shaping and wherein the method of



extrusion is either direct or indirect.

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36. A method according to claim 1, wherein the crystal nuclei are generated by a method in which two or more liquid alloys having different melting points that are held superheated to less than 50° above the liquidus temperature are mixed either directly within the insulated vessel having a heat insulating effect or along a trough in a path into the insulated vessel, such that the temperature of the metal as mixed is either just above or below the liquidus temperature.

37. A method according to claim 36, wherein the two or more metals to be mixed are preliminarily contacted with respective jigs each having a cooling zone such as to produce metals of different melting points that have crystal nuclei and which have attained temperatures just either above or below the liquidus temperature.

38. A method according to claim 1, wherein the top surface of the semisolid metal that is held within the insulated vessel and which is to be fed into the forming mold is removed by means of either a metallic or nonmetallic jig during a period from just after the pouring into said vessel but before the molding temperature is reached and, thereafter, said semisolid metal is inserted into an injection sleeve.

39. A method according to claim 18, wherein the outer vessel is heated either from inside or outside or by induction heating, with such heating being performed only before or after the insertion of the holding vessel into the outer vessel or continued throughout the period not only before but also after said insertion.

40. A method according to claim 9, wherein the aluminum alloy is replaced by a zinc alloy.